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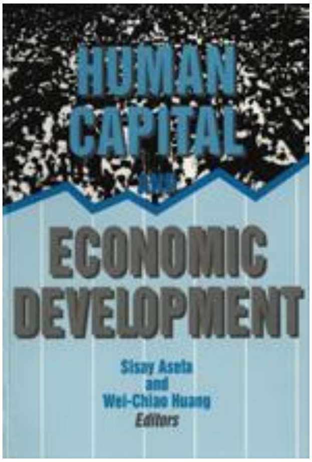

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The Very-Long-Run Effect of Human Capital on Human Progress

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This article is my first attempt to state a general theory of human progress in connection with the concept of population numbers and human capital. The theory is presented with only a sketchy formal framework and with little supporting data; those elements must await a longer presentation.

The question addressed here is: What is the rock bottom cause of so many of the world's population now being long-lived and endowed with much wealth and a high standard of living, with an even larger proportion likely to enjoy these benefits in the coming decades, whereas people did not have those advantages 10,000, 2,000, 1,000, or even 200 years ago? The obvious answer—almost a definition—is that current technology A_{1993} is a sum of increments to knowledge dA in the past. And these dA were produced by people and therefore must have been influenced by human numbers. One may add that the cultural, political, economic, and social systems of the past were also a factor, and perhaps a more important factor than numbers. I shall argue, however, that those systems were themselves a function of human numbers together with the economic levels of past societies; this is one of the main points of the paper.

Why did the rapid progress of the past two centuries not begin centuries or millennia earlier, or not begin until sometime in the future? Was there something extraordinary about the human numbers P or the level of technology A in the year 1700 or so? Probably not. But we must notice one crucial correlation: Both P and A as well as the income Y all began to rise rapidly about that time. That rise represented an unprecedented tripling or more within a century or two and was the first such event in all the thousands of years of human history.

The answer I offer is that the size of the human population, as measured by both population density $P/\ln d$ and P together with the technology these people produced, is the root cause of the speed of progress. More operationally, if the world's population had not grown at all since, say, 10,000 years ago, or if population had not grown as fast as it did over the millennia, the material condition of humanity could not have progressed to its present state. To put it differently, if the rate of population growth had been different (and had resulted in different total populations at various times) than actually was the case, the extraordinary period of the past two hundred years of falling mortality and increasing income would have happened either much later or much earlier. Furthermore, one cannot say this of any other variable unless it would primarily alter human numbers—as, for example, a climatic change would have affected food production, or the quantity of energy easily available would have improved survival probabilities. If there were not an effect on human numbers, such a change would have affected the amount of leisure and perhaps the mode of getting a living, for example, herding versus hunting, but would not have affected the speed of economic progress.

Even bestowing a library of today's knowledge upon a small population in the past probably would not have led to rapid progress. Indeed, we know from the experience of India and China and other poor countries until recently that the existence of such knowledge can coexist with continuing backwardness. This leads to the question of whether that fact does not contradict the basic thesis of this paper. I think it does not, because we already see the inexorable process of rapid modernization in these countries, despite having economic-political-social systems not well designed for such progress, systems that kept the modernization from happening earlier (as it happened earlier in Japan). And in turn, the combination of numbers and the existence of knowledge, together with the demand for the fruits that knowledge brings about, are inducing huge changes in the economic systems so as to accommodate more rapid progress, as the thesis in this paper suggests; this has been the case most vividly for 700 million rural Chinese whose agriculture was essentially privatized starting in 1979. So, taken altogether the evidence available as of 1993 concerning the poor though well-populated countries is not inconsistent with the thesis offered here.

Two lines of evidence are adduced to support the basic proposition: (1) correlations of population size P and density $P/\ln d$ with the rate of knowledge production dA, and (2) evidence that other relevant variables are a function of P and Y. I also present some scrappy evidence to show that population is not only correlated with knowledge production but also is a causal variable. And I present theory and data to disprove the proposition that the "natural" availability of natural resources has been a crucial force.

I will argue (in connection with the causal concept used here) that there is no nonbiological variable "deeper" than human numbers that one can point to as being responsible for the population growth that occurred, as one can point to population growth as being responsible for the growth in income and the evolution of institutions and patterns of behavior that were necessary for the progress that occurred. That is, I will argue that unlike all other nonbiological variables, population growth is exogenous in the process.

Many laypersons would say (and I agree with them) that the proposition stated here is entirely obvious: If there were no people, there would be no "human capital" to create the knowledge that leads to progress, and hence there would be no progress. But this answer is not at all obvious or agreed-to in the view of many scholars, when speaking of long-run as well as of short-run progress. So the work required here is not the demolition of a strawman.

It is a crucial element of the model stated here that population growth and density affect the structure of law and tradition and political institutions. If this were not so, structures that are incompatible with an improvement in technology and the long-run standard of living could have remained in place indefinitely, thereby preventing further progress. It is therefore an important part of this essay—and perhaps its most important novelty—to offer fine-structure evidence for this process of population-induced social change.

The complex web of relationships of endemic and epidemic disease, and knowledge of them, with population density and total numbers also is an important part of the analysis.

The strategy of the article will be as follows. The next section presents the theory offered here. I then review the skimpy time-series and cross-sectional evidence on the relationship of population to the rate of economic growth in the long run, and ask about the possibility that other variables could explain the observed long-run economic growth; at best, these data make a *prima facie* but not a compelling case for the theory. Next I digress to explore one particular topic which has been at the root of thinking about population economics for three thousand years: the relationship of numbers of people to supplies of natural resources. I follow that with a presentation of evidence on the relationship of population to structural factors that affect the rate of economic progress; this section is the heart of the paper; if given the space that the subject deserves, the section would take up most of the book which this subject properly requires (and which may yet come forth if luck holds).

Various sections draw heavily upon my earlier work on the subject of population growth; this article may be thought of as part of an evolutionary process in knowledge development.

A Stylized Description of Human Progress

In order to set the scene before launching into more formal work, here is a stylized description of the long-run history of the process of human progress. The first hominids came into being without any body of knowledge that they themselves created, but instinctive knowledge of how to survive was programmed into their genes just as with every other species. And the early people may have learned some additional techniques by observing other animals that happened to live within their ken, such as techniques of building shelters and gathering food. Such imitations may have been the first sort of learning that is distinctively human in its cumulative adaptation to the world about us. (I have recently read that there seems to be a similar process of imitation among apes, but it is questionable whether the knowledge can be handed down from one generation to the next.)

The hominids then increased their population, just as other new species (if successful) increase their populations by spreading across new territory into niches that will sustain them. At some point—whether population had stabilized by that time or not is unknown—new discoveries were made. These discoveries might have included the knowledge of fire and of stone implements—the latter occurring at least two million years ago, according to Leakey (1981, p. 78). Each discovery improved the ability of our ancestors to survive and allowed numbers to increase faster than before the discovery; even simple stone tools must have had a large effect on the rate of population growth. (Fire and stone tools are "invention-pull" rather than "population-push" technology, requiring no increase in labor and therefore being of immediate utility rather than waiting for further population growth to make them profitable.) But recent work with genetics suggests that about 65,000 years ago the population was only about 100,000 and declined to about 10,000 before expanding again ("Research News," *Science*, October 1, 1993).

Why did rapid economic progress not occur much earlier—say 100,000 or a million years ago? Was it just an accident that rapid progress ever began, and could that accident just as easily have taken place many millennia earlier? I think not; I cannot imagine any single event that could have come along and made a big difference at an earlier time. The early invention of nuclear power obviously is inconceivable, but even had a nuclear reactor and full instructions been dropped on earth by Martians, it would have been less use than a meteorite. Utilization of nuclear power had to wait for the accumulation of the nexus of human numbers and knowledge.

Only a biological or environmental difference that would have altered the nutrition and/or the rate of fertility and of subsequent survival—either climate or the appearance of a remarkable new easy-to-obtain food source (or the opposite) or a change in the digestive system, for example—could have altered the speed of economic progress through the millennia. If numbers had been greater earlier on, there would have been more people to invent and develop new discoveries such as new ways of herding and cropping. Larger numbers also would have meant greater need for such improvements earlier on, which would have speeded up their adoption after invention in those cases where adoption is not immediately profitable (Boserupian population-push inventions).

Other kinds of differences could not have changed the rate of progress, I contend. The earliest hominids had elements of a social system in their genetic programs, just as do apes; for example, incest was surely practiced only infrequently, as with other species of animals. But while there must have been some variations in social system from one band of hominids to another, it would not have been possible for them to live with a modern form of social system that is consistent with modern rates of rapid progress, such as democracy, over an area as large as hundreds or even tens of miles in each direction, even if someone had invented it; such modern systems could not be used until population and technology (and the standard of living) had increased many times over.

Would history have been very different if numbers had stayed at the level they were at the time of Athens' glory? I contend that we would not have reached the technology and the standard of living we now enjoy—especially our unprecedented life expectancy, which began to lengthen rapidly only 250 years ago—if our numbers had remained at the few hundreds of millions on earth at the peak of Rome and Greece.

This essay is an attempt to support with theory and data the thoughts sketched out in the above paragraphs.

The Theoretical Framework

My thesis is that (1) higher density and (2) larger total populations, in individual societies and on earth altogether, were *necessary* conditions for progress. The extent to which they were (and are) also *sufficient* conditions depended in the past upon the nature of the societies at the time. Particular societies certainly have been capable of *retrogression* in the face of population growth. The analysis suggests, though it cannot constitute more than a speculation on the matter, that conditions of twentieth century transportation and communications have rendered such long-term retrogression less and less likely, however.

The appropriate form for the inquiry is to ask: What would be the effect of a major change in some variable x? For example, what effect would there have been if the Anglo-Saxon legal system had somehow been transmitted to North American natives in the year 1000? Would this have had a major effect on their economic and demographic growth? The theory points to variables that are the key conditions of readiness for growth—the nexus of population numbers together with the stock of knowledge and the level of the standard of living.

An alternative theory, which I believe to be less compelling than the theory stated above, is that the invention of new knowledge *by itself* would raise the standard of living. For example, if starting in, say, the year 1000 societies had somehow decided to educate a much larger number of people and then put them to work in knowledge-producing pursuits, would that have raised the rate of progress of the living standard? Surely there would have been some increase in progress, but how much? The work of Boserup (1965), together with my analysis of inventions into those that are and are not immediately adopted without appropriate demand conditions (Simon 1977, chapter 8; 1978; and 1992, chapter 3), shows that some newly invented knowledge can remain dormant for a long time if demographic conditions are not appropriate for its adoption at the time.

A secondary and related thesis is that the income level of a society is the other most important determinant of significant material and technical variables such as health, knowledge, physical and social mobility, and communications. I will not develop this thesis here.

Conceptual Frameworks and the Time Horizon

The appropriate conceptual framework for the analysis of the effects of population depends upon the length of horizon and upon the level of economic development (which has the aggregate in the long-run correlate with the historical date). These are some of the relevant frameworks.

1. For the very short run in a *subsistence* society, the framework of Malthus is appropriate; the coming of more mouths or a deterioration of natural conditions leads to diminishing returns in agriculture and causes there to be less to eat for the average person. For the very short run in a *developed* economy, the appropriate framework is a system of equations which may have hundreds of variables and thousands of connections, as seen in the spaghetti-like large-scale multisector models used for forecasting by consultants to government and business. In these short-run models for both subsistence and developed economies, the stock of technology and the nature of institutions—and sometimes even the size of the labor force—are considered fixed.

2. Somewhat longer-term models consider physical and human capital to vary. The growth of technology usually is considered to occur at

a constant rate. The structures of political institutions, law, work behavior, and tradition are considered to be fixed. The income level and the size of the labor force are important variables in such models.

3. An even longer-run model of a subsistence society allows for the nonconstant endogenous introduction of new technology. The alternative frameworks of the long-run Malthusian dynamics (quite different from the short-run Malthusian model mentioned above) and of the Boserup analysis for subsistence agriculture are complementary rather than opposing, as we shall see below. For developed economies, the recent crop of endogenous-growth models (including my own work on endogenous knowledge in connection with population growth) make technology endogenous, but do not include some of the variables included in the shorter-run models. These endogenous-growth models include only income, population, and knowledge as independent variables, and consider the structures of law and tradition only peripherally, if at all. Population growth may or may not be endogenous in this sort of model.

4. The longest-run model, the heart of this paper, contains population growth at the earliest date in the dynamic system as the sole exogenous variable; the structures of law, tradition, and other institutions are endogenous variables, along with the standard of living, technology, and subsequent population growth. From such a model one can deduce the proposition that if biological or climatological elements had caused the rate of population growth to be faster than it actually was, humanity would have had greater numbers than actually existed at various times in the past; and each state in its development, including the present state of high material culture and low mortality, would therefore have reached centuries or millennia earlier.

Population and Knowledge

The most difficult analytic issue concerns the relationship between the causal roles of population and of knowledge. They are the only two variables about which one can reasonably say: If the stock of this variable had been much lower than its actual stock in year t, the state of humanity would have been vastly poorer in the year $t + x$ than it actually was. All other variables, such as the stocks of private physical capital and prime farmland, are likely to be replaced rather quickly if there is a sudden catastrophic loss; not so with population and knowledge.

The rock bottom causal element of long-run human progress is the combination of population and knowledge. They are as much inseparable parts of the same process as are the brain and the sexual organs. It makes as little sense to ask which is the "original" cause as about chicken and egg. Even the earliest humankind could not have survived and grown without such technology as cutting tools and fire; and in turn, the knowledge of these techniques came from human beings.

Indeed, the interpenetration of population and technology is shown by the fact that history consists of both the Boserupian "population-push" and the Malthusian "invention-pull" combinations of an invention and population growth, in which causation runs from one of these two forces in one case and to it in the other. (In Simon 1977, chapter 8; 1978; and 1992, chapter 3, I provide geometric and arithmetic theory for these two processes, together with extensive historical examples.)

The key point is that no *other* element was as essential as the combination of knowledge and human numbers—not institutions, law, physical capital, natural resources, or any other element. Humankind could live in a variety of settings of these variables and produce livable forms of them when they are completely absent; not so with knowledge and human numbers.

Evidence on the Long-Run Progress-Population Connection

This section reviews the available time-series and cross-sectional evidence on the relationship of population to the rate of economic growth in the long run. The purpose is to show that there is indeed a connection to be investigated; these data make a *prima facie* case for the theory, but it is only *prima facie* and not a compelling case; to make a persuasive case requires the later sections of the paper. Then there is discussion of the possibility that variables other than population could explain the observed long-run economic growth.

Population Size and the Standard of Living

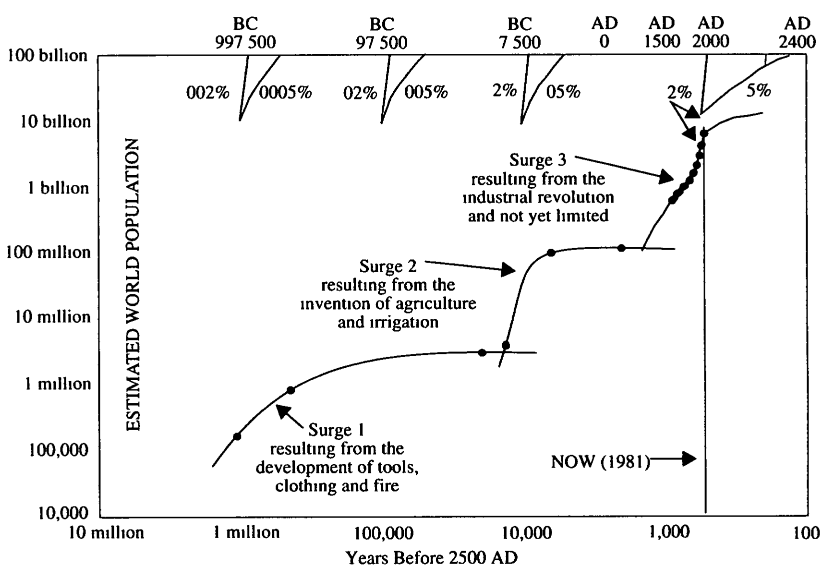
Time-series evidence.

The first set of time-series evidence is stylized figures of crucial variables over the very long run. The purpose of the graphs is to show how all these variables moved in much the same general way, with population moving earlier than the others. The lack of any precise data and the consequent absence of ups and downs in the series prevents any explicit statistical exploration of causality.

For the longest period of the existence of human beings as a species—from, say, 20,000 years ago until 6,000 or 7,000 years ago—population growth was very slow, and hence total population and population density were low. This growth might be described by a straight line if plotted on semilog paper, but such a plot would obscure the point of the graph, which is that the rate of early growth was infinitesimal.

A slightly less broad view is shown in figure 1, whose logarithmic scale reveals the rapid increases in population starting with the onset of the agricultural, industrial, and postindustrial "revolutions."

Figure 1. Growth of the Human Population of the World Over the Last One Million Years



SOURCE: After Deevey 1960, by Tinsley 1980, p. 11
NOTE: Please notice that the axes are logarithmic.

During most of the past millennia, economic progress undoubtedly was slow or nonexistent (which is proven by jobbing backwards; spreading total growth over such a long period of time implies a very low average rate), though it is very difficult to find meaningful indicators. Perhaps the most meaningful measure of economic progress through the ages, both because of its intrinsic importance and because we have some reliable data, is life expectancy; it increased only slowly from the minimum level at which the species could be sustained rather than go extinct. The most striking aspect of the increase in life expectancy for world populations at various dates over the past 10,000 years is the rapid recent increase in the richer countries since the eighteenth century, and in the poorer countries in the second half of the twentieth country; this is an absolutely unprecedented event, and the most important development in the history of humankind from the standpoint of economics as well as noneconomic welfare.

Some evidence that one might consider as disconfirming the basic proposition of this paper is found in the long-run early history. The total number of human beings who ever lived before, say, 6000 years ago was not small; a reasonable estimate is that of the 77 billion human beings born from 600,000 BC to 1962 AD, 12 billion lived before 6000 BC (with 42 billion from 6000 BC to 1650 AD, and 23 billion from 1650 AD to 1962 AD), to be compared with the more than 5 billion who may be alive now.[1] Of course many of the people born in earlier years died at young ages. But even so, the number of years of human life lived on earth in the long-ago past was not small relative to any recent period. Are these numbers inconsistent with their total intellectual production in light of the thesis of this paper? Later I shall argue that because the production of knowledge depends upon the existing stock of knowledge as well as the population size and density, the slow growth of knowledge in early millennia does not confute the basic thesis.

The tool-using and tool-making revolution kicked off the rapid rise in population around 1,000,000 BC The aid of various implements gave the food gatherer and hunter access to the widest range of environments. But when the productivity gains from the use of primitive tools had been largely exploited, the rate of population growth fell.

The next rapid jump in population started perhaps 10,000 years ago, when people began to keep herds and cultivate the earth rather than simply foraging for wild plants and game. Once again the rate of population growth abated after the initial productivity gains from the new technology had been exploited, and population size settled down to a near-plateau compared to the rapid growth experienced for a while. The known methods of making a living constituted a constraint to further population growth once the world's population reached a certain size.

These two previous episodes of sharp rise and subsequent fall in the rate of population growth suggest that the present rapid growth—which began perhaps 300 or 350 years ago, in the 1600s—may settle down again when, or if, the gains from the new industrial and agricultural knowledge that followed the "industrial revolution" begin to peter out. And population size may again reach a near-plateau and remain there until another "revolution" due to another major change in technology, society, or psychology. Of course the current knowledge revolution may continue without foreseeable end, and population growth may or may not continue as long as the revolution does. Either way, in this long-term view population size adjusts to productive conditions rather than being an uncontrolled monster.

To return to the many humans who lived in early millennia but produced little new knowledge: If progress were a function of the number of human minds alone, the total medical progress during the long period before, say, 6000 BCE should have been as great as in the last 50 years, during which life expectancy increased rapidly and hugely. But it was not so. Nor was the absence of rapid population growth as a stimulus a reasonable explanation; the presence of sickness and the danger of death certainly have been in all times a sufficiently powerful motivation for major efforts at innovation. So this immediately requires that a theory be more complex than the total number of persons alive among whom the spark of invention and progress might somehow arise spontaneously.

The most reasonable additional explanatory variables are these: (1) Population *density* conduces to the production and transmission of new ideas, according to the theory of Simon Kuznets and the study by Kelley (1972) of Higgs's (1971) data on American inventiveness. (2) Production of new knowledge is influenced by the stock of existing knowledge; the more existing ideas that may be built upon, the greater the propensity to create new ideas. (This is demonstrated for the case of patents in England over many centuries by Simon and Sullivan 1989.)

Evidence from the modern period demonstrating that economic growth in the developed countries has been faster in more recent decades than in more distant decades when population was smaller is found in the work of Maddison, Fellner, and Meguire (the latter finding that the U.S. data do not square with the other countries' data, though it is logically necessary that growth now be faster than, say, 200 years ago (see Simon, forthcoming, for a review of this evidence).

Cross-sectional evidence.

Cross-national comparison of the data for recent decades reveals that higher population density is correlated with a higher rate of economic growth (Simon and Gobin 1980).

Population Growth and the Growth of Technology

The next evidence to be presented concerns the bivariate relationships between population and such other variables as knowledge and productivity over the period for which at least some data exists to check for causality.

A long-run measure of the stock of the most important kind of knowledge—agricultural technology—is the number of persons that a single agricultural worker can feed. The complementary variable is the proportion of the labor force that works in agriculture; it was nearly the entire labor force throughout human history. But in about 1600 the proportion began to fall in the richest countries, and it now has reached less than 2 percent in some affluent countries; the decline has unmistakably begun in the poor parts of the world, too. This also is the best long-term measure of the standard of living and of productivity.

A closely related measure of agricultural technology as indicated by agricultural productivity per person is the price in labor time of a given quantity of food. This price has fallen in the U.S. since 1800 by a factor of perhaps 20 (Simon 1992).

A measure of technology related to productivity per person is productivity per unit of land—the amount of land employed to feed an average person. The quantity of land needed to feed a person has declined extraordinarily over the years, in best practice by an astonishing factor of perhaps 25 million, compared with hunting and fishing and by almost as much in standard practice, indicating an extraordinary increase in productivity.

Shifting now to technology in metals production: Analogous to the decline in the price of food as measured by the amount of time required to produce it is the decline in the prices of metals—an enormous fall with respect to the price of labor in rich countries and large even compared with the consumer price index over the past two centuries (Simon 1981; forthcoming), continuing a trend observable for 4,000 years. The supply of copper may be viewed in this context as a final good and a component measure of the standard of living; it may also be seen later as an element in the progress of productivity. The line of causation from population to price seems rather clear here; there is no other reasonable explanation of the increase in supply except an increase in demand and in the supply of minds to produce new ways to increase the supply and invent new substitutes.

The speed and cost of transportation is another good whose technology has measurably improved. (Transport is a good in itself, as well as affecting the supply of food.) In just the past two centuries, speed has risen from the 3-mile-an-hour walking pace of a human or the somewhat faster pace of a horse or ship to hundreds of miles per hour on land and thousands of miles per hour in the air (not even counting space travel).

Long-run data on the increase in the stock of knowledge as measured by the number of scientific journals and patents in the past five centuries, and in human capital as measured by numbers of literate persons and persons with given amounts of education (the absolute numbers are more relevant than the proportions, though the proportion is also of interest), are sufficiently well known as to not need further discussion here.

Some writers have suggested Greece and Rome as counterexamples. But their rates of discoveries of important new ideas were faster in their peak periods of population than before or after those periods (see Simon 1981).

Another long period whose data are relevant is the Dark Ages. Currently most commentators, such as Pirenne, agree that after population declined, the standard of living fell and progress ceased despite the increase in agricultural land per agriculturalist and the consequent drop in the price of land; this might have been caused by the decline in total population or the lack of growth or both. Much the same seems to have been true in the years after the Black Death. In contrast, the rapid increases in population starting around 1000 and 1500 were accompanied by buoyant economic progress.

Simon and Sullivan (1989) show that in England from 1500 to 1800 population and knowledge (as measured by patents) do not just grow together secularly, but there is a causal relationship between them when other variables are held constant.

Cross-sectional evidence.

A work tradition beginning with Rostas (1948) shows that when pairs of countries are compared, growth in productivity is higher in those industries in which production is relatively larger; in light of the association between higher production and higher population *ceteris paribus,* this suggests that higher population leads to higher increases in productivity.

Another relevant cross-sectional study is that of Glover and Simon (1975), which shows that road density is greater where population is more dense. And roads are a crucial element in the transmission of knowledge.

Natural Resources and Population

As North (1981) has written, natural resources have been a major element in discussions of population growth since the first such recorded discussions. The constraint of natural resources must therefore be considered before one can appreciate a theory of human progress in the past despite the perceived limits of natural resources—progress that is without known bounds in the future as natural resource constraints lessen rather than tighten.

Astonishingly, the importance of land and other natural resources diminishes with every passing decade. Such was the great discovery of Schultz about land in 1951, and of Barnett and Morse (1963) about agricultural and mined resources. Their forecasts based on the historical record and theoretical analyses have been borne out perfectly by events since then, as food and all metals, indeed, all natural resources, have continued to get cheaper rather than more expensive.

Natural resources are the most dramatic examples of the fundamental process at work in the long course of economic progress: Increasing population or rising income raises demand for a commodity, which usually implies a higher price. The higher price represents opportunity—for businesses to make a profit and for inventors and institutions to realize their desires to make creative social contributions. Most prospective discoverers fail to find solutions to the problem, and they pay the price themselves. One or more succeed in finding the needed solutions. And usually the outcome, most unexpected though very important, is that the solution leaves humanity better off than before the problem arose. That is, we end up with cheaper resources than before the problem of the rise in price first occurred.

The story of this process at work in the case of energy since about the fifteenth century in England—from wood to coal to oil to nuclear power—is told at length in my 1981 book, as is the story of copper during the 4000 years since Hammurabi.

A formal model of this process using the example of farmland may be found in Simon and Steinman (1991) or in Simon (1992, chapter 5). We simulate the model with meaningful parameters and analyze how the course of food prices and land availability will change over centuries. We also analyze the steady-state properties of the system to show how it is consistent with long-run growth in the standard of living as human numbers increase.

Very-Long-Run Processes

It should help substantiate the exogeneity of growth to provide evidence on the disaggregated sinews of the process; this is the task of the present section. This section contains the new substantive material conveyed by this article, material which provides the evidence for the propositions that (1) the rate of progress is a function of human numbers; and (2) in the very long run all social and economic dimensions are indeed a function of population size and density and constitute endogenous intermediate variables rather than independent causal variables.

The elements that this section will touch on include the development of markets, social and economic organization, law, disease, and evolved cultural patterns. Here our time horizon is so long that the phenomena that change over such a long period usually are not even mentioned in the context of population economics. These phenomena have been studied little, and because the ground is new the amount of data is small. Hopefully the paucity of data will not mislead the reader about the importance of these phenomena.

The Development of Markets

The size of the market depends upon both the *number of people* and the *level of income*. The number of persons multiplied by their average level of income measures aggregate income, and is perhaps the basic measure of the size of the market. (Of course the sizes of submarkets will be affected by the *distribution* of the total income among persons, but that can be left aside here.) There is a presumption, then, that more people imply bigger markets.

Increased population density also leads to better-organized markets. Hicks (1969) and North (1981) have shown the connection between these variables throughout history at the local and regional level. As noted earlier, this phenomenon was seen vividly after the depopulation of the Black Death. Despite higher wages and increased land availability to cultivators, overall economic conditions apparently were less favorable. There was general economic depression as a result of the disappearance of markets that in turn was caused by lack of people and products to support markets.

A look at mircoeconomic theory with population and market growth in mind immediately suggests many avenues through which there is improved competition when population is larger rather than smaller, especially the effects of having more rather than fewer producers and sellers. In general, a larger number of competitors leads to a more responsive and more rapidly changing marketplace.

Cities, along with infrastructure, seem to have been a crucial precondition of the industrial revolution in England, Holland, and elsewhere. The existence of cities requires relatively dense populations in surrounding areas. Cities and markets are closely related phenomena. Pirenne's magisterial analysis (1925/1969) depends heavily on population growth and size. Larger absolute numbers of people are the basis for increased trade and consequent growth in cities, which in turn strongly influenced the creation of an exchange economy in place of the subsistence economy of the manor.

According to Pirenne, growth in population causing cities to grow also reduced serfdom by offering serfs legal haven in the city, as memorialized in the saying "Town air makes free."

Disease

The evolution of the disease environment is another of the crucial evolutionary processes that population density and growth have influenced. Density of population affects the virulence of disease; sometimes it makes disease spread faster, as in the case of epidemics, and sometimes it suppresses it, as in the case of malaria. And there are further complications: Sometimes increased virulence leads later to immunities that check the spread of diseases. McNeill (1977) describes how the evolution of the disease environment has been greatly influenced in complex ways by population density and therefore by population growth.

For most of the great diseases, the growth of population in earlier centuries represented a one-time "investment" of our species into developing resistance to mass killers; once our ancestors had suffered this experience, later generations could go about their lives with less threats.

A different sequence: By causing the land to be cropped closely, increasing population density reduces the virulence of malaria, the greatest killer of all; an important example was South China, which was only colonized after this process had made it habitable.

A body of knowledge about the prevention and cure of diseases also has evolved, much of it in a prescientific trial-and-error process; an older example is the practice of quarantine. More recently, health knowledge has begun to evolve from systematic scientific work; an example is smallpox vaccination. Such advances in medical practice can be attributed to the combination of a scientific attitude and a greater base of scientific medical knowledge, both of which were enhanced by the industrial revolution; these advances occurred in countries that were experiencing the industrial revolution, and did not occur in countries such as India and China that were outside the ambit of the industrial revolution. This greater capacity to deal actively with the disease environment may be seen as a consequence of population growth.

Events during the industrial revolution are instructive in this regard. The causes of the fall in the death rate are also somewhat unclear, though in recent years scholars have made rapid progress in understanding the phenomenon. Some part of the mortality drop may have been unconnected with economic progress; the climate may have improved and yielded better crops, the rat population may have spontaneously altered its species composition in such fashion that the rigors of plague diminished, and the disease environment may otherwise have become less dangerous. Some part of the improvement may stem from economic progress in only very indirect fashion, if at all, notably through shorter periods of breastfeeding and hence less inhibition of pregnancy. But economic progress was surely responsible for most of the improved life expectancy.

Economic progress, which interactively is the result of population growth, helped people live longer by providing better diets. McKeown (McKeown and Brown 1955; McKeown 1985) has argued forcefully that "the slow growth of the human population before the eighteenth century was due mainly to lack of food, and the rapid increase from that time resulted largely from improved nutrition" (1985, p. 29). Fogel's (1989) work agrees. (The importance of nutrition is surprisingly difficult to establish conclusively, however.)

Economic progress also helped people live longer through development of the physical infrastructure of society, especially provision of purer communal drinking water. Such improvements were not mainly intended to improve health and reduce death, but they nevertheless did so to an important degree. Building such infrastructure requires farming to be sufficiently efficient so that society can afford to employ people on such community projects. Also required is that the population be sufficiently large and dense that such projects are economical. The same is true for roads and other communication systems that contributed to the spread of health technology. (See earlier discussion of road density and population density.)

In some places greater population density must have had short-term negative effects upon health by temporarily lowering the standard of living—the Malthusian "positive check." But in the longer run, the overall result of population growth on the incidence of disease clearly has been positive.

Social and Political Organization

Though it is difficult to pin down statistically, the effect of population size and density upon social and political organization and its role in economic development is given ever greater importance by such scholars as Jones (1981) and McNeill (1963).

Population density and size seem to be related to the mode of organization and the size of the government sector. Stevenson (1968) argues that increasing density leads to better-articulated organization of society; this seems plausible, but the phenomenon is difficult to quantify.

The relationship of population growth to the abolition of feudalism and slavery is controversial and needs further investigation.

It is enlightening to keep in mind a question that is frequently asked: If more people cause there to be more ideas and knowledge, more growth of markets and cities, and hence higher productivity and income, why did not the modernization revolution begin in India and China? This requires more lengthy discussion than this introduction to the subject permits; suffice it to say that it ties into discussion of what Jones calls "the European miracle."

In Europe there seems to have been a nexus of interconnections between loosening of feudal ties, growth of cities, personal economic freedom, political freedom, openness of societies, competition among European states, economic advance, popular government, and population growth. McNeill (1963), Jones (1981) and others have suggested that over several centuries the relative looseness and changeableness of social and economic life in Europe, compared to China and India, helps account for the emergence of modern growth in the West rather than in the East. Change implies economic disequilibria which, as Schultz (1975) reminds us, imply exploitable opportunities leading to augmented effort. (Such disequilibria also cause the production of new knowledge, it would seem.)

Evolved Cultural Patterns

The processes of evolutionary growth extend into technical knowledge, social institutions, language, law, morals, rituals, and practices, all of which affect human productive capacities just as does the evolving stock of land, tools, shelter, and other physical capital—one of the most interesting aspects of this subject. It is plausible that these aspects of human life changed only under the pressure of necessity, as represented by increased population, and then in turn the new conditions influenced the growth of population. If humankind had not developed patterns of behavior and association that increased rather than decreased the amounts of resources available to us, we would not still be here. If, as humankind's numbers increased (or even as numbers remained nearly stationary), behavior had led to diminished supplies of plants and animals, less flint for tools, and disappearing wood for fires and construction, I would not be writing these pages, and you would not be reading them. These processes cannot now be documented for prehistory, of course, but we have begun to develop knowledge about the operation of similar processes in recent decades and the present, e.g., changes in institutions for agricultural research (Hayami and Ruttan 1987).

Evolved cultural patterns include *voluntary exchange among individuals*, and the markets that function to provide resources in increasing quantities, as discussed above; institutions that pass on knowledge, such as schools; libraries, legends and storytellers, all of which store knowledge; and monasteries, laboratories, and research-and-development departments which produce knowledge.

Humankind has evolved into creators and problem solvers to an extent that people's constructive behavior has outweighed their destructive behavior, as evidenced by our increasing life expectancy and richness of consumption. And in recent centuries and decades, this positive net balance has been increasing rather than decreasing. This view of the human as (on balance) a builder conflicts with the view of the human as destroyer, which underlies the thought of many doomsayers.

Paradoxically, *rules and customs that lead to population growth* rather than to population stability or decline may be part of our inherited capacity to deal successfully with resource problems in the long run, though the added people may exacerbate the problems in the short run. Such rules and customs probably lead to long-run success of a society in two ways. First, as noted above, high fertility leads to increased chances of a group's survival, other things being equal. For example, though the Parsis of India have been, as individuals, very successful economically, as a people they seem doomed to the failure of disappearance in the long run due to their marriage and fertility patterns. Second, high fertility leads to resource problems, which then lead to solutions to the problems that usually leave humanity better off in the long run than if the problems had never arisen, in the process discussed earlier. In a more direct chain of events, rules and customs leading to high fertility yield an increased supply of human ingenuity, which responds productively to the increased demand for goods.

Particularly slow to change are *basic institutions of law and convention.* These institutions tend to evolve gradually rather than being altered by political upheaval or legislation. Hayek (1989) argues that property rights and the family are the two most important institutions in determining the economic progress of a nation. He suggests that they, as well as the rest of the rich tapestry of cultural patterns, develop by a process of cultural selection wherein communities that grow in numbers are more likely to have their institutions be dominant in the wider world than are groups that do not increase in population. Much of this evolutionary process has taken place over thousands of years. But the effects were important for economic development; for example, the system of Anglo-Saxon common law and its protection for property surely aided the course of the industrial revolution in England. Therefore, these slow-moving effects of population increase should not be forgotten in our survey of demographic consequences.

Linguistics may be able to cast some light on the rate of change of language to population size. In this respect language may be an important model for change in other subtle elements in culture.

The effect of population density and size upon the refinement and the changes in direction that occur in the law has been hinted at by preliminary studies in the United States relating the size of state to the extent to which decisions are cited. This theme needs to be developed.

Most difficult of all to pin down is the effect of population growth and the industrial revolution, and their proximate effects discussed earlier, upon individual psychology and small-group sociology. Adam

Smith remarks that "the progressive state is in reality the cheerful and the hearty state to all the different orders of the society. The stationary is dull; the declining melancholy." And it was a commonplace during the earlier part of the industrial revolution that industrial work discipline, including attention to the daily time schedule for work hours, was both important and slow to develop. Many writers have discussed the mentality of progress and the notion of systematic scientific progress; both ideas were concomitants of the industrial revolution. However accurate these observations about psychological and small-group effects may be, however, they do not stand on the same level of demonstrated fact as do the phenomena discussed in the earlier parts of this paper. Yet the brevity of this treatment should not be taken as suggesting that these factors may not be of great significance. (On the other hand, perhaps human nature should be seen as having been changed relatively little by the industrial revolution. The meaning of "little" and "much" are quite subjective, of course.)

Summary and Conclusions

This paper outlines a theory of the role of "human capital" that fits the very-long-run trends. It discusses some of the elements that affect the *speed of adjustment* to population change, conditions which are different at different times in history and vary from place to place.

1. The state of knowledge clearly is the dominant element that varies in the long run. It is affected by population growth and density, as knowledge in turn affects population growth and density.

2. Interrelated with changes in knowledge and production technique are changes in the structure of society. These structural changes also are influenced by population variables, and vice versa. There is increasing recognition of the importance of social and economic structure in economic development in even the short run. And population affects these forces in the long run.

3. The growth of markets, with their many associated phenomena, has been a function of population size and density. More people mean both more buyers and more sellers, and hence less monopoly and more competition and competitive effort.

4. Slowest-changing are the habits, rituals, language, law, morals, and all manner of social institutions, including sexual and childraising practices. All of these elements are subject to processes of evolutionary change. They not only are affected by population variables, but in turn influence population growth and—differentially—the likelihoods of survival of different human groups. Also disease affects in both directions. Here we have moved all the way to full biology-like evolutionary thinking, which is at the other end of the methodological spectrum from the sort of physics-like thinking that we apply in very-short-run analysis when the relevant elements are known and fixed. But the evolutionary processes in question are social and cultural rather than biological.

NOTE

1 A more recent estimate is 3.8 billion before 40,000 BCE, 39 billion from 40,000 BCE to the start of the Common Era, and 22 6 billion from the year 1 up until the year 1750, plus another 10 4 billion from then until 1950, and 4 3 billion from then until 1987, for a total of perhaps 80.3 billion (Bourgeois-Pichat 1989, p 90). The fact that, although Bourgeois-Pichat did not make reference to Desmond (1975), the two estimates are so close to each other lends confidence to them.

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